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**Barry**

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(54) **DEVICE AND METHOD TO LOCATE AND READ AN IMPLANTED DEVICE USING ULTRASOUND**

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(71) Applicant: **INTEGRA LIFESCIENCES**  
**SWITZERLAND SÀRL**, Le Locle  
(CH)

(72) Inventor: **Donald Barry**, Franklin, MA (US)

(73) Assignee: **INTEGRA LIFESCIENCES**  
**SWITZERLAND SÀRL**, Le Locle  
(CH)

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**2205/581** (2013.01); **A61M 2205/583**  
(2013.01)

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**2039/226**; **A61M 2205/502**

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Primary Examiner — Sanjay Cattungal

(74) Attorney, Agent, or Firm — Troutman Sanders LLP

(57) **ABSTRACT**

A subcutaneous implantable device has one or more adjustable settings with a setting device configured to selectively change between the one or more adjustable settings. An indicator, having an ultrasound reflection enhancement, indicates each particular setting of the one or more adjustable settings.

**12 Claims, 7 Drawing Sheets**

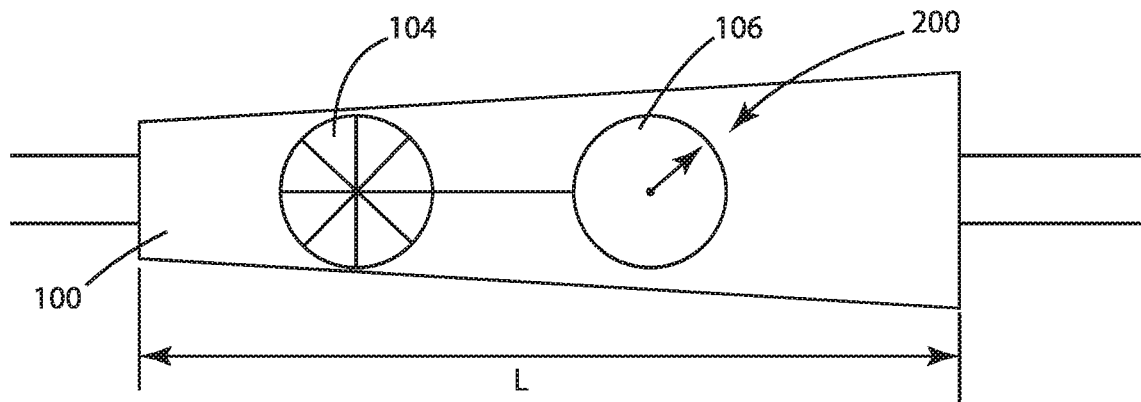
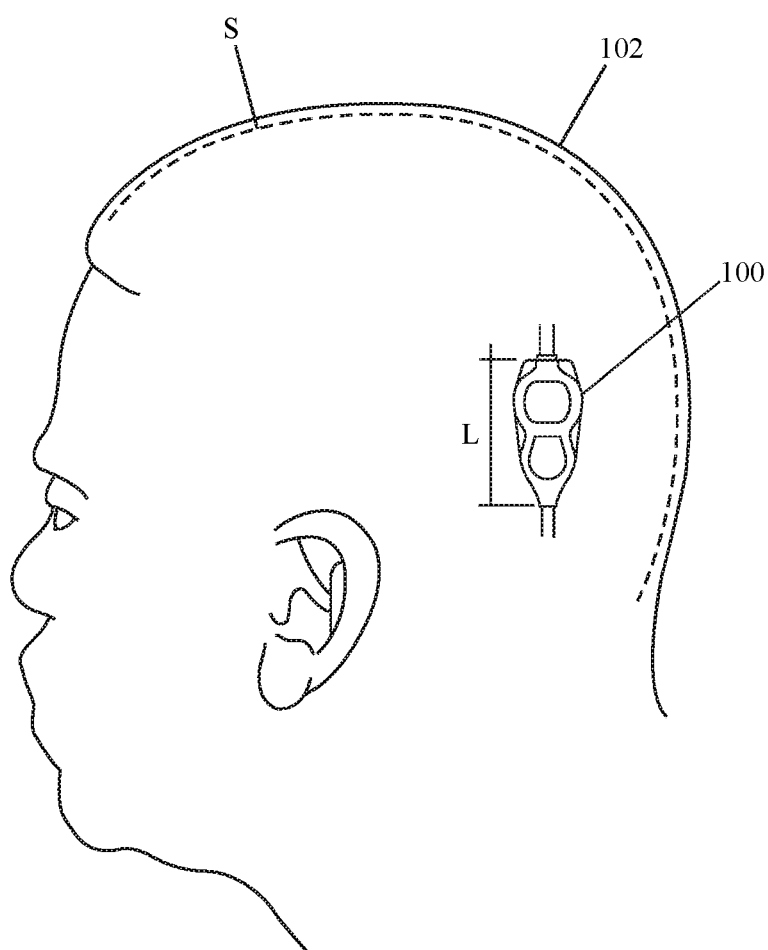
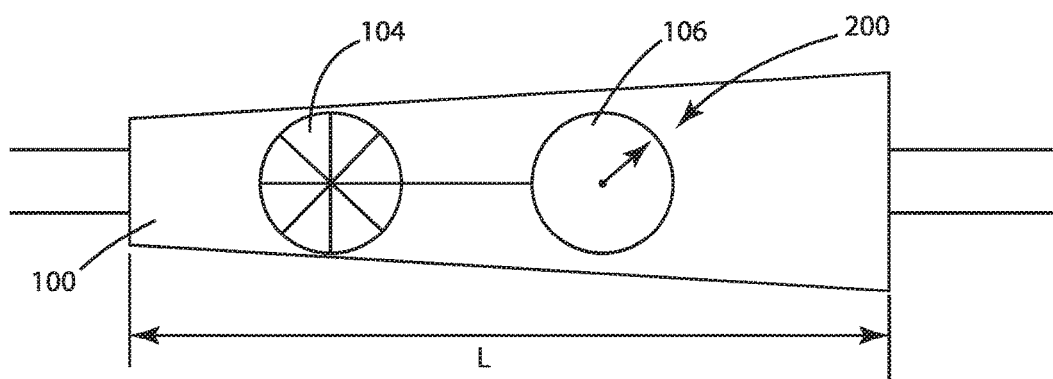


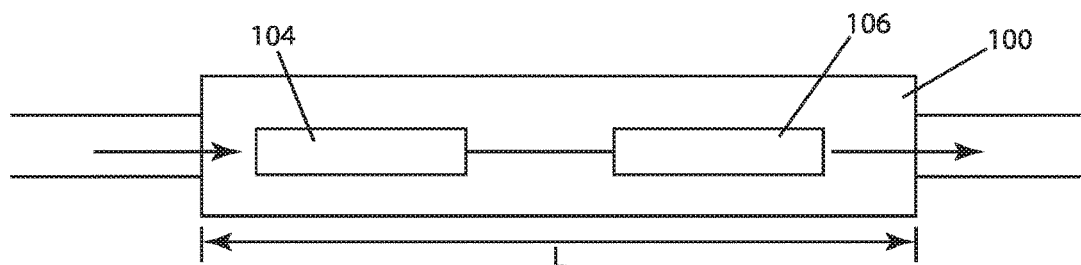
Fig. 1



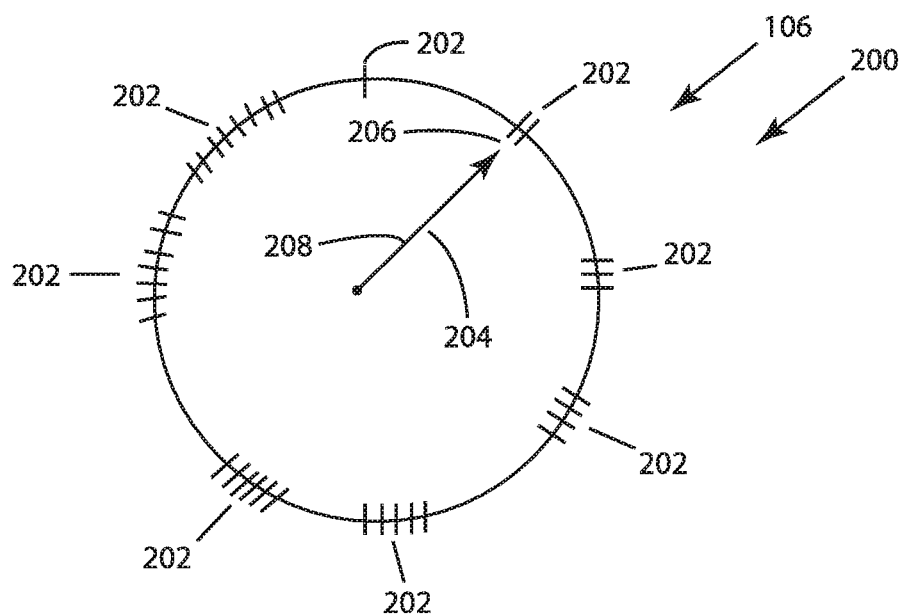
**FIG. 2A**



**FIG. 2B**



**FIG. 3**



**FIG. 4**

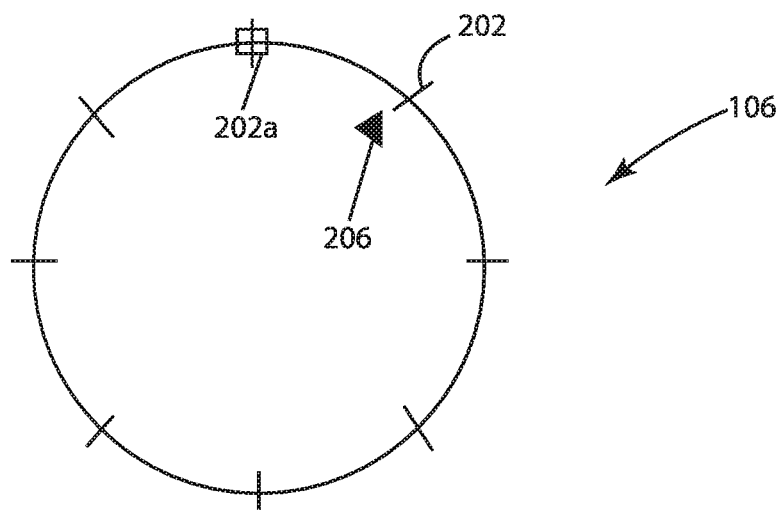


FIG. 5

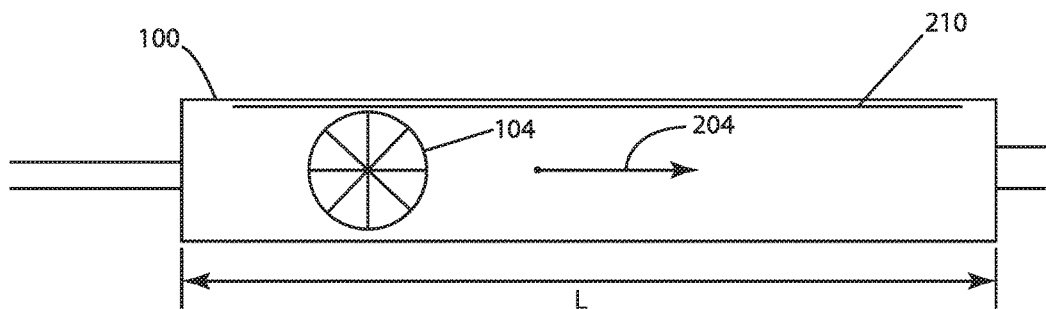


FIG. 6

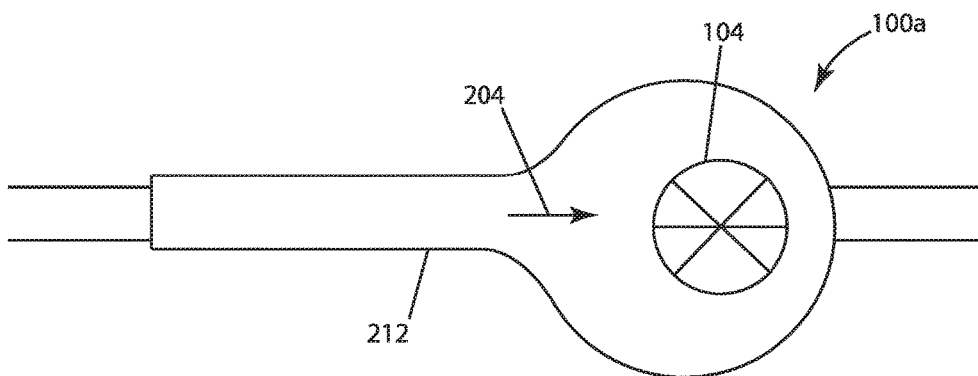


Fig. 7A

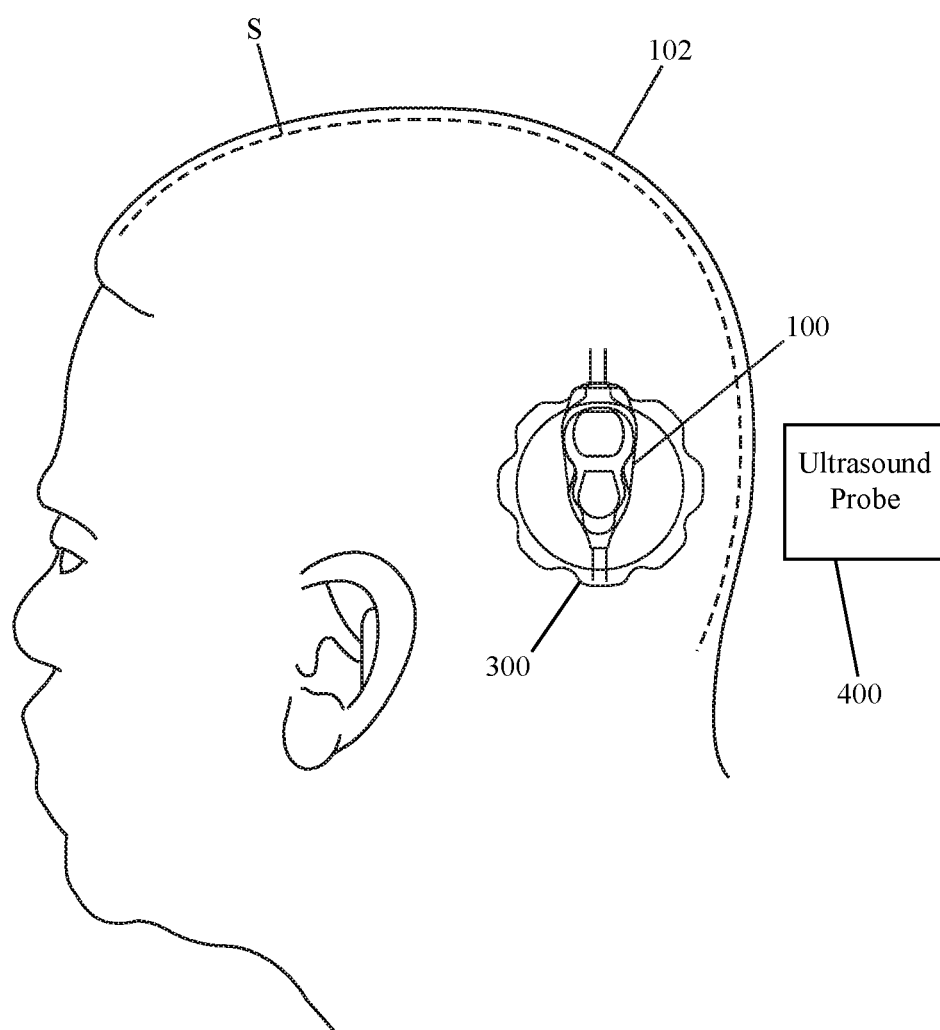


Fig. 7B

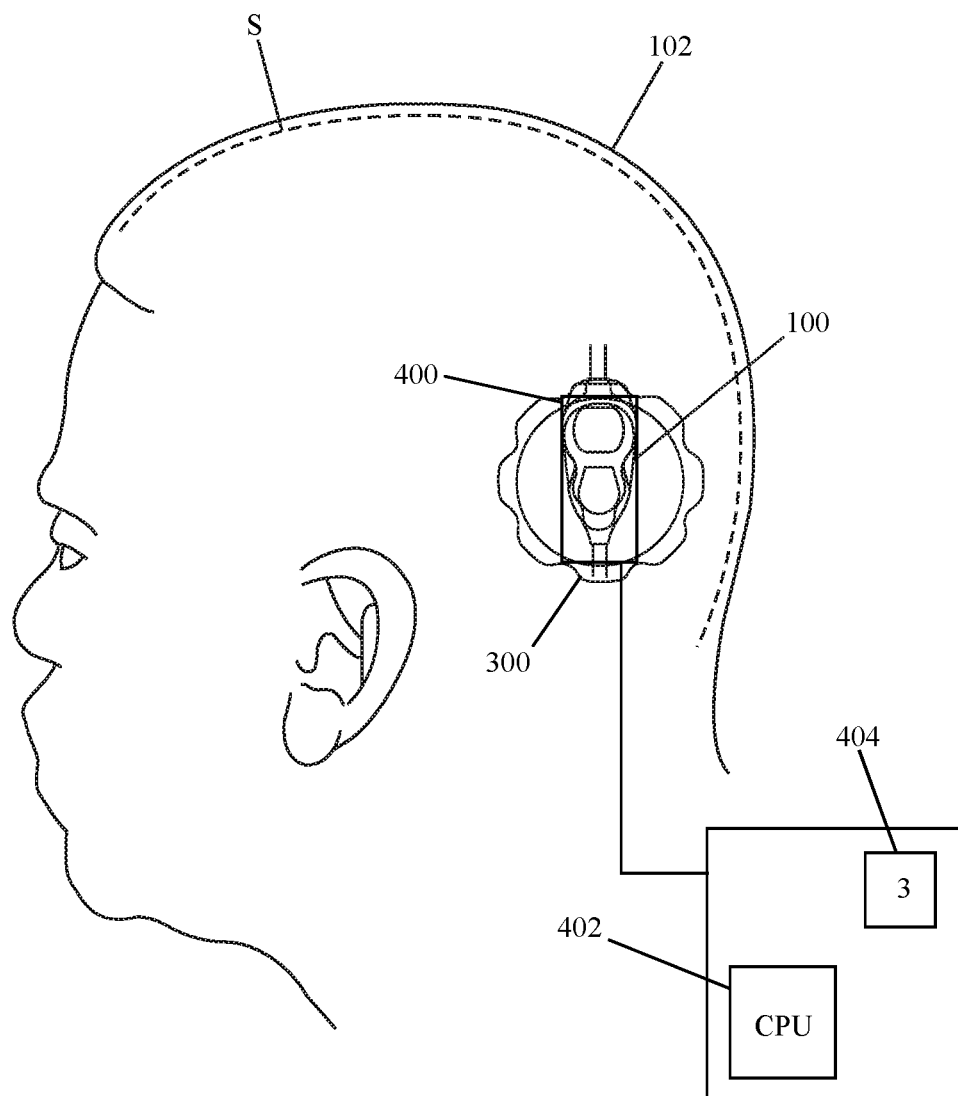


Figure 8

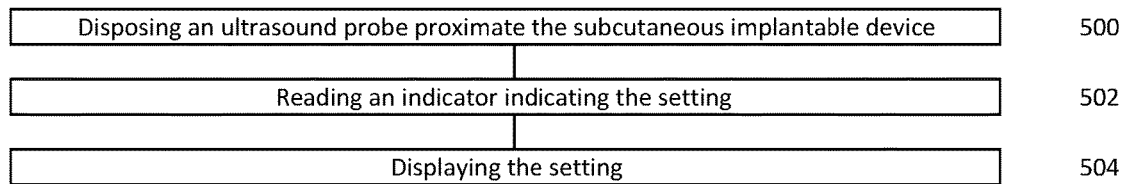
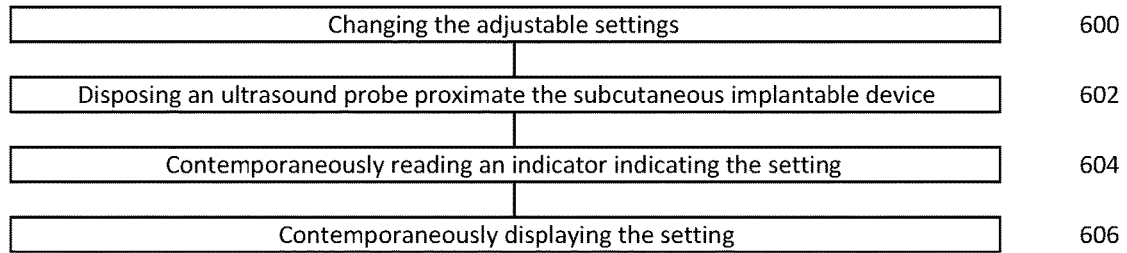


Figure 9





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# DEVICE AND METHOD TO LOCATE AND READ AN IMPLANTED DEVICE USING ULTRASOUND

## FIELD OF THE INVENTION

The invention relates generally to surgically implantable fluid drainage systems. More specifically, the invention relates using ultrasound to locate the adjustable valves and their settings.

## BACKGROUND

Hydrocephalus is a neurological condition caused by the abnormal accumulation of cerebrospinal fluid (CSF) within the ventricles, or cavities, of the brain. Hydrocephalus, which can affect infants, children and adults, arises when the normal drainage of CSF in the brain is blocked in some way. Such blockage can be caused by a number of factors, including, for example, genesetting predisposition, intraventricular or intracranial hemorrhage, infections such as meningitis, or head trauma. Blockage of the flow of CSF consequently creates an imbalance between the rate at which CSF is produced by the ventricular system and the rate at which CSF is absorbed into the bloodstream. This imbalance increases pressure on the brain and causes the ventricles to enlarge. Left untreated, hydrocephalus can result in serious medical conditions, including subdural hematoma, compression of the brain tissue, and impaired blood flow.

Hydrocephalus is most often treated by surgically inserting a shunt system to divert the flow of CSF from the ventricle to another area of the body, such as the right atrium, the peritoneum, or other locations in the body where CSF can be absorbed as part of the circulatory system. Various shunt systems have been developed for the treatment of hydrocephalus. Typically, shunt systems include a ventricular catheter, a shunt valve and a drainage catheter. At one end of the shunt system, the ventricular catheter can have a first end that is inserted through a hole in the skull of a patient, such that the first end resides within the ventricle of a patient, and a second end of the ventricular catheter that is typically coupled to the inlet portion of the shunt valve. The first end of the ventricular catheter can contain multiple holes or pores to allow CSF to enter the shunt system. At the other end of the shunt system, the drainage catheter has a first end that is attached to the outlet portion of the shunt valve and a second end that is configured to allow CSF to exit the shunt system for reabsorption into the bloodstream. Typically, the shunt valve is palpable by the physician through the patient's skin after implantation.

Shunt valves, which can have a variety of configurations, can be designed to allow adjustment of their fluid drainage characteristic after implantation. It is generally preferred to enable external adjustment of the pressure threshold to avoid invasive surgical procedures each time an adjustment is required. In some shunt systems, the shunt valve contains a magnetized rotor to control the pressure threshold of the valve. Physicians can then use an external adjustment mechanism, such as a magnetic programmer containing a powerful magnet, to adjust the pressure threshold of the shunt valve. One issue with magnetically programmable valves is a potential for unintentionally adjusting the valve by the misapplication of an external magnetic field. Unintentional adjustment of the valve could lead to either the overdrainage or underdrainage of CSF, which can result in dangerous conditions, such as subdural hematoma. Thus, the setting position for adjustable CFS or hydrocephalus shunt

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valves must be verified after adjustment, or, after exposure to strong magnetic fields such as MRI.

Known methods to externally read or verify the setting of the valve can be burdensome or inaccurate. With some adjustable valves, x-ray images are used to determine the current setting of the valve, before and after adjustment, which is very burdensome. With other adjustable valves, the orientation of the rotor in the valve can be read magnetically, using a magnetic compass-like device positioned above the valve, outside the skin of the patient. However, these can be inaccurate because they can be interfered with by extraneous magnetic fields caused by Earth or local devices.

Thus, a need exists for an easier and more reliable way to verify the position of the valve's settings.

## SUMMARY

The present invention includes examples of a subcutaneous implantable device having one or more adjustable settings. This includes a setting device configured to selectively change between the one or more adjustable settings, and an indicator indicating each particular setting of the one or more adjustable settings and comprising an ultrasound reflection enhancement. In other examples, the subcutaneous implant can have the indicator as part of the setting device. Alternately, the indicator can further have one or more setting marks, each mark identifying each particular setting of the one or more adjustable settings, an identifier identifying each mark as set by the setting device, and the one or more setting marks and the identifier comprise the ultrasound reflection enhancement.

Another example of the subcutaneous implantable can include an orientation axis determining a positional orientation of the device as implanted, an axis identifier disposed along at least a portion of the orientation axis and comprising an ultrasound reflection enhancement, and the indicator indicates the particular settings in relation to the axis identifier. Further, examples have a body, enclosing at least the setting device, a perimeter outlining the body, an outline mark along at least a portion of the perimeter and comprising an ultrasound reflection enhancement, and the indicator indicates the particular settings in relation to the outline mark. The body can be asymmetric.

An example of an adjustment tool for a subcutaneous implantable device having one or more adjustable settings has an adjusting tool configured to change the one or more adjustable settings, an ultrasound probe configured with the adjusting tool to take real-time readings of the one or more adjustable settings as the adjustment tool makes the change, and a display linked to the probe and indicating the setting. The adjustment tool can also be in a kit with a subcutaneous implantable device having one or more adjustable settings. The implant can have a setting device configured to selectively change between the one or more adjustable settings; and an indicator indicating each particular setting of the one or more adjustable settings and comprising an ultrasound reflection enhancement. The adjustment tool can also have the indicator with one or more setting marks, each mark identifying each particular setting of the one or more adjustable settings, an identifier identifying each mark as set by the setting device, and the one or more setting marks and the identifier comprise the ultrasound reflection enhancement.

Other examples of methods to determine a setting of a subcutaneous implantable device having one or more adjustable settings can be disposing an ultrasound probe proximate the subcutaneous implantable device, reading an indicator indicating the setting of the one or more adjustable settings

based on an ultrasound reflection enhancement on the indicator, and displaying the setting. The method can also include changing the one or more adjustable settings using an adjusting tool, and the reading and displaying steps are performed contemporaneous with the changing step.

#### BRIEF DESCRIPTION OF THE DRAWINGS

This invention is described with particularity in the appended claims. The above and further aspects of this invention may be better understood by referring to the following description in conjunction with the accompanying drawings, in which like numerals indicate like structural elements and features in various figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

The drawing figures depict one or more implementations in accord with the present teachings, by way of example only, not by way of limitation. In the figures, like reference numerals refer to the same or similar elements.

FIG. 1 is an illustration of the valve implanted in a patient; FIGS. 2A and 2B are top and side sections views, respectively, of an example of an implantable valve of the present invention;

FIG. 3 is an example of an indicator of the present invention;

FIG. 4 illustrates an example representation of the indicator as seen by ultrasound;

FIG. 5 illustrates an example of a valve with an axis mark and identifier of the present invention;

FIG. 6 illustrates another example of a valve of the present invention;

FIG. 7A illustrates an example of the valve adjustment tool and ultrasound probe in use;

FIG. 7B illustrates an example of the valve adjustment tool with ultrasound probe in use;

FIG. 8 illustrates a flow chart of an example of a method of the present invention; and

FIG. 9 illustrates a flow chart of an example of a contemporaneous method of the present invention.

#### DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth by way of examples in order to provide a thorough understanding of the relevant teachings. However, it should be apparent to those skilled in the art that the present teachings may be practiced without such details. In other instances, well known methods, procedures, components, and/or circuitry have been described at a relatively high-level, without detail, in order to avoid unnecessarily obscuring aspects of the present teachings.

FIG. 1 illustrates a generalized implantable device **100** with typically two or more settings. In the below examples, an implantable shunt valve is described, but any adjustable subcutaneous implanted device can be improved using examples of the invention. In examples, the valve **100** is implanted under the skin **102** of a patient's skull **S**. The valve **100** can have a long axis **L** along which the fluid flows. Once implanted, the valve is under the skin and typically covered by hair. Additionally, the area surrounding the valve may experience localized swelling, especially after surgery.

FIGS. 2A and 2B illustrate the top and side cut-away views of valve **100** which can include a setting device **104** to adjust the valve **100**. In some examples, the settings can be changed under the influence of a directed magnetic field. Also, in an example, the valve **100** can have a plurality of

predetermined settings corresponding to a plurality of predetermined rotational orientations of the setting device **104**. In some examples, the plurality of settings comprises eight settings. It is to be understood that the valve **100** can be any settable, implantable valve, including a magnetically settable one. Further, an indicator **106** can be part of or in communication with the setting device **104** to provide information regarding the actual setting of the valve **100**. Thus, as the setting device **104** is changed to change the flow parameters of the valve **100**, the indicator **106** can reflect these changes, even in real time.

Examples of the invention use ultrasound technology to detect the position of the valve's setting. In one example, illustrated in FIG. 3, the indicator **106** can be selectively treated with ultrasound reflective materials **200**. These materials reflect more ultrasound signal than any other feature of the valve **100** or the surrounding skin and more to increase the accuracy of the reading. The indicator **106** can be treated with ultrasound setting marks **202**. Each mark **202** can indicate a valve setting. Each setting mark **202** can be a unique identifier or just one or a few marks **202**. FIG. 3 illustrates the indicator **106** as a circular element, akin to a watch face, but it is known that any indicator **106** can be used by one of skill in the art. In the illustrated example, there are a number of elements that make up the setting mark **202** and each identify a numerical position on the indicator (i.e. 1=|; 2=||; 3=|||; 4=||||), alternately, the setting mark **202** can be the numeral itself. In another example, just the first setting mark **202a** can differ from the rest and there is a protocol to reading the remaining marks (e.g. the setting mark to the left of the first setting mark is setting **8**, and the one to the right is setting **2**, etc.) (see, FIG. 4 as an example).

The indicator **106** can also include an identifier **204**. The identifier **204** identifies the setting of the valve **100**, in this example, by its position relative to the setting marks **202**. The identifier **204** can also be selectively treated with ultrasound reflective materials to assist in determining its position. For example, just the tip **206** closest to the setting marks **202** or the entire hand **208** can be treated. Note that the changing of the setting device **104** can alter the position of either the setting marks **202** or the identifier **204**, as either can move relative to the other. FIG. 4 illustrates the indicator **106** of above example as seen by just ultrasound echo. Due to the selective treatments, only the setting marks **202** and tip **206** of the identifier **204** are visible.

Another example of indicating the setting of the valve **100** can be based on the orientation of the valve **100** itself relative to the position of the identifier **204**. FIG. 5 illustrates an example of an ultrasound axis mark **210** parallel to the long axis **L** of the valve **100**. Here once an operator understands the orientation of the valve using the ultrasound axis mark **210**, the setting noted by the identifier **204** can be discerned based on the relative position of the two. Further to the example of using the orientation of the valve **100**, FIG. 6 illustrates an example where a portion or the entire valve **100a** is coated with an ultrasound outline mark **212**. In this example, the valve **100a** is not symmetric and the outline of the valve **100a** can be selectively treated with ultrasound reflective materials to form the outline mark **212**. Again, once an operator understands the position of the valve **100a** from its asymmetric shape, the position of the identifier **204** relative to the shape as defined by the outline mark **212** can be discerned, and thus the valve setting determined. Further, in certain examples, the outline mark **212** does not have to enclose the entire area and/or perimeter of the valve **100a**,

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the mark or marks **212** need, at a minimum, to identify the non-symmetric shape so a user can determine valve orientation.

Turning now to “ultrasound” and selectively treating elements of the invention with ultrasound reflective materials. Ultrasound herein in examples is used in its broadest meaning of the use of sound waves to determine subcutaneous elements. This determination can be reported to the user as visual or non-visual indicators. In the visual sense, a typical ultrasound can produce images in real time of subcutaneous elements in accordance with their reflective properties. Non-visual indications can also be encompassed in examples of the invention. Here, either an audio cue can be used determine the setting, or a processor can interpret the ultrasound results and report back to the user just information regarding the setting of the valve.

Selectively treating elements of the invention with ultrasound reflective materials indicates that the element is at least partially or fully made from or treated with materials or surface features that increase the ability of the material to reflect ultrasound waves. This can be by a selection of materials for both the valve **100** and the elements to be ultrasonically identified. Alternately, small air bubbles can be entrained into plastic elements to exploit the known difference in reflection between solids and air. Furthermore, other examples can utilize distinct surface features, like properly sized and spaced pits, to change the reflectance. For example, other ultrasound reflection enhancing treatments may consist of mechanical corner cube indentations on the surface of the indicator **106**, which direct more of the energy back to the source. Additionally, spacing, banding, or striations between marks can also be used as unique identifiers. In addition, any means, materials, or methods known to one of ordinary skill to improve ultrasound wave reflection are contemplated in these examples.

Addressing the method of using the invention, since the identification of the valve setting is performed by ultrasound, the position can be determined in real time and/or contemporaneously with the setting of the valve. Real time determination can happen as soon as the medical professional removes a valve adjusting tool **300**, used to alter the valve’s settings. Once removed an ultrasound probe **400** can be placed over the valve **100** to read the image of the location of the indicator **104**, identifier **206** and/or the marks **202**, **210**, **212**. Even more immediate feedback can be provided further to examples of the invention. FIG. 7A illustrates the patent with the installed valve **100**. Here, the adjusting tool **300** can be in place over the valve **100** and an ultrasound probe **400** can be separately placed nearby. The probe **400** can read the identifier **206** as it is being moved by the movement of the adjusting tool **300**. In this example, the identifying features **104**, **206**, **202**, **210**, **212** can be configured to be read perpendicular or oblique to the top surface of the valve **100**. As the adjusting tool **300** is set on top of the valve **100**, the probe **400** can come along side and identify the markings sidelong.

FIG. 7B illustrates a similar concept that can correct for the sidelong reading. In this example the ultrasonic probe **400** is built into the adjusting tool **300**. This example allows the combination tool/probe **300**, **400** to take a top down reading and adjust the valve simultaneously. This example can also simplify locating the valve **100** under the patient’s skin **102**. Normally, to locate the valve **100** under the skin **102**, the user typically palpates the skin **102** until she can feel the valve **100**. Now the medical professional can run the combination tool/probe **300**, **400** over the patient’s skin until an identifying feature **104**, **206**, **202**, **210**, **212** can be

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located. As noted above, the probe **400** can also include a processor **402** and a display **404** to provide real-time results from the probe **400**. The processor **402** can interpret the information from the probe **400** and display **404** either an image or just a valve setting. Alternately, the display **404** can be speaker and provide audio information regarding the valve setting.

FIG. 8 illustrates an example of a method of the present invention. The method includes determining a setting of a subcutaneous implantable device (e.g. implanted valve **100**) having one or more adjustable settings. The user or medical professional can dispose the ultrasound probe **400** proximate the subcutaneous implantable device **100** (step **500**). The probe can read the indicator **106** indicating the setting of the one or more adjustable settings based on an ultrasound reflection enhancement **200** on the indicator **106** (step **502**). The read setting can be displayed on the display **404** (step **504**).

FIG. 9 is an example of the method when the adjusting tool **300** and the probe **400** are used in tandem. Here one or more adjustable settings of the valve **100** are changed the using an adjusting tool **300** (step **600**) and the user or medical professional can dispose the ultrasound probe **400** proximate the subcutaneous implantable device **100** (step **602**). Examples of this step can be the probe and tool **400**, **300** are a single device, or the indicator **106** can be configured to allow for sidelong indications and reading. Then the readings of the indicator **106** indicating the setting of the one or more adjustable settings based on an ultrasound reflection enhancement **200** on the indicator **106** (step **604**) can happen contemporaneously with the adjustment, or as fast as the indicator **106** can calibrate to the newly adjusted setting. With the contemporaneous reading the setting can also be displayed contemporaneously, or in real time (step **606**).

While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that the teachings may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all applications, modifications and variations that fall within the true scope of the present teachings.

What is claimed is:

1. A subcutaneous implantable device having one or more adjustable settings, comprising:
  - a body of the subcutaneous implantable device constructed with ultrasound reflective material;
  - a setting device positioned on the body and configured to selectively change between the one or more adjustable settings associated with fluid flow parameters of the device; and
  - an indicator positioned on the body and indicating each particular setting of the one or more adjustable settings and comprising an ultrasound reflection enhancement comprising ultrasound reflective material wherein the implantable device is configured to operate with an ultrasound probe to take real-time readings of the one or more adjustable settings.
2. The subcutaneous implantable device of claim 1, wherein the ultrasound reflective material is configured to reflect more ultrasound signal than any other feature of the subcutaneous implantable device or the surrounding skin and increase accuracy of the readings.
3. The subcutaneous implantable device of claim 1, wherein the indicator further comprises:

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one or more setting marks, each mark identifying each particular setting of the one or more adjustable settings; and

an identifier identifying each mark as set by the setting device,

wherein the one or more setting marks and the identifier comprise the ultrasound reflection enhancement.

4. The subcutaneous implantable device of claim 1, further comprising:

an orientation axis determining a positional orientation of the device as implanted; and

an axis identifier disposed along at least a portion of the orientation axis and comprising an ultrasound reflection enhancement,

wherein the indicator indicates the particular settings in relation to the axis identifier.

5. The subcutaneous implantable device of claim 1, further comprising:

the body enclosing at least the setting device;

a perimeter outlining the body; and

an outline mark along at least a portion of the perimeter and comprising an ultrasound reflection enhancement, wherein the indicator indicates the particular settings in relation to the outline mark.

6. The subcutaneous implantable device of claim 1, wherein the body is asymmetric.

7. An adjustment tool for a subcutaneous implantable device having one or more adjustable settings, comprising:

a body of the subcutaneous implantable device constructed with ultrasound reflective material configured to reflect more ultrasound signal than any other feature of the subcutaneous implantable device;

an adjusting tool configured to change the one or more adjustable settings;

an ultrasound probe configured with the adjusting tool to take real-time readings of the one or more adjustable settings associated with fluid flow parameters of the implantable device as the adjustment tool makes the change; and

a display linked to the probe and indicating the setting.

8. The adjustment tool of claim 7, further comprising:

a subcutaneous implantable device having one or more adjustable settings, comprising:

a setting device configured to selectively change between the one or more adjustable settings; and

an indicator indicating each particular setting of the one or more adjustable settings and comprising an ultrasound reflection enhancement.

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9. The adjustment tool of claim 8, wherein the indicator of the subcutaneous implantable device further comprises:

one or more setting marks, each mark identifying each particular setting of the one or more adjustable settings; and

an identifier identifying each mark as set by the setting device,

wherein the one or more setting marks and the identifier comprise the ultrasound reflection enhancement.

10. The adjustment tool of claim 8, wherein the indicator of the subcutaneous implantable device consists of eight setting marks, each mark identifying each particular setting of the one or more adjustable settings; and

an identifier identifying each mark as set by the setting device,

wherein the setting marks and the identifier comprise the ultrasound reflection enhancement comprising materials that reflect more ultrasound signal than any other feature of the subcutaneous implantable device or the surrounding skin and increase accuracy of the readings.

11. A method of determining a setting of a subcutaneous implantable device having one or more adjustable settings, comprising the steps of:

disposing an ultrasound probe proximate the subcutaneous implantable device, the subcutaneous implantable device comprising: a body having ultrasound reflective material; a setting device positioned on the body and configured to selectively change between the one or more adjustable settings associated with fluid flow parameters of the implantable device; and an indicator positioned on the body and indicating each particular setting of the one or more adjustable settings and comprising an ultrasound reflection enhancement comprising ultrasound reflective material;

reading the indicator indicating the setting of the one or more adjustable settings based on the ultrasound reflection enhancement on the indicator; and

displaying the setting.

12. The method of claim 11, further comprising the step of:

changing the one or more adjustable settings using an adjusting tool,

wherein the reading and displaying steps are performed contemporaneous with the changing step.

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